Center Innovation Fund: LaRC CIF

Real-Time Probabilistic Structural Health Management Using Machine Learning and GPU Computing Project

Completed Technology Project (2015 - 2016)

Project Introduction

The proposed project seeks to deliver an ultra-efficient, high-fidelity structural health management (SHM) framework using machine learning and graphics processing unit (GPU) computing, exploring how far the latency limits can be pushed towards real-time feedback. The approach will be to parallelize and unify two recent Langley-developed damage diagnosis and prognosis algorithms that utilize statistical surrogate models for efficient uncertainty quantification. External expertise from the Old Dominion University Department of Computer Science will be leveraged to assist in parallelizing these algorithms for emerging many-core high performance computing architectures. The result will be low latency software which can use experimental sensor data to probabilistically characterize structural damage and then simulate how that damage will propagate and affect a vehicle's remaining useful life.

An effective structural health management (SHM) system provides sensor data to a diagnosis algorithm that characterizes structural damage and then relies on prognosis software to simulate how that damage will affect a vehicle's remaining useful life. The critical nature of SHM applications motivates high-fidelity and low-latency feedback while the noisy sensor data and approximate computational models used necessitate rigorous uncertainty quantification (UQ). Unfortunately, high-fidelity modeling implies time-consuming simulations and UQ often requires tens of thousands of them. Furthermore, the algorithms that drive probabilistic damage diagnosis are traditionally sequential in nature, preventing the straightforward application of parallel processing to alleviate the computational burden. Thus, achieving such an all-encompassing SHM framework is extremely challenging from a software development standpoint.

Two recent NASA Langley studies address the probabilistic diagnosis and prognosis problems independently. Both employ machine learning to replace expensive physics-based simulations with statistical surrogate models to reduce the computation time. While demonstrating significant gains in efficiency, both employed conventional sequential implementations and therefore do not scale well with problem complexity. A new but widely accepted work, however, opens the door for parallelism in such probabilistic analyses. The objective of the proposed research here is to utilize this novel parallel algorithm to migrate the Langley-developed diagnosis and prognosis methods to emerging many-core high performance computing (HPC) architectures. Ultimately, the project aims to then combine the two GPU-accelerated algorithms into one comprehensive framework for low-latency, high-fidelity SHM with UQ.

Anticipated Benefits

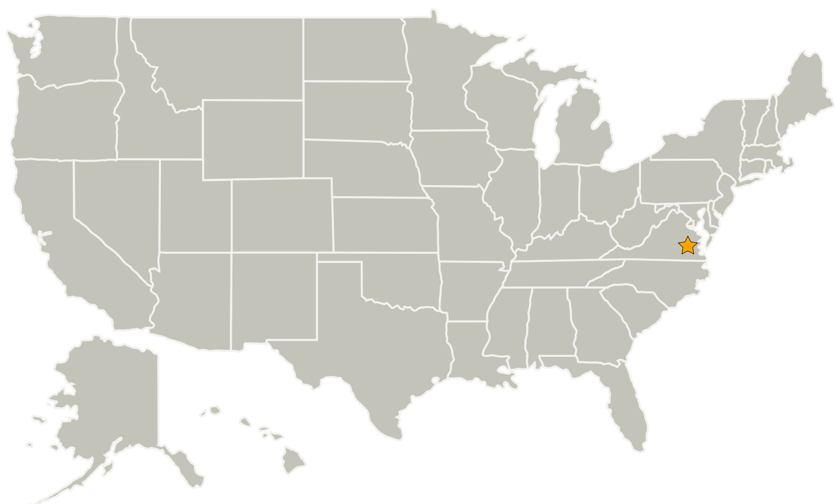
This project promotes a transition to condition-based, online SHM that will impact deep space & long-duration missions where there is an inability to

Real-Time Probabilistic Structural Health Management Using Machine Learning and GPU Computing Project

Table of Contents

inspect/maintain/repair. Moving from time-based maintenance and routine inspection to condition-based monitoring can also have economic benefits. Furthermore, the development of high-fidelity, online SHM allows for design limits to be pushed while maintaining safety.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Langley Research Center(LaRC)	Lead Organization	NASA Center	Hampton, Virginia

Co-Funding Partners	Type	Location
Old Dominion University Research Foundation(ODURF)	Academia	Norfolk, Virginia

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Langley Research Center (LaRC)

Responsible Program:

Center Innovation Fund: LaRC CIF

Project Management

Program Director:

Michael R Lapointe

Program Manager:

Julie A Williams-byrd

Project Manager:

Sandra P Walker

Principal Investigator:

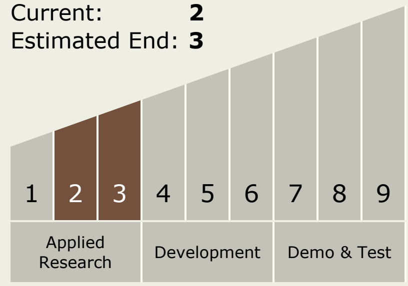
James E Warner

Co-Investigator:

Patrick E Leser

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX13 Ground, Test, and Surface Systems
  └ TX13.1 Infrastructure Optimization
    └ TX13.1.6 Test, Operations, and Systems Safety